

SCS:kdn 04/07/03 180925

PATENT

Attorney Reference Number 245-53153

Application Number 09/369,679

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Paul et al.

Art Unit: 1763

Application No. 09/369,679

CERTIFICATE OF MAILING

Filed: August 5, 1999

For: MICROLAMINATION METHOD  
FOR MAKING DEVICES

Examiner: Allan W. Olsen

Date: April 7, 2003

I hereby certify that this paper and the documents referred to as being attached or enclosed herewith are being deposited with the United States Postal Service on April 7, 2003, as First Class Mail in an envelope addressed to: COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

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COMMISSIONER FOR PATENTS  
WASHINGTON, D.C. 20231

## DECLARATION OF BRIAN KEVIN PAUL UNDER 37 C.F.R. § 1.132

I, Brian Kevin Paul, hereby declare as follows:

I. I am a coinventor of the referenced application. I currently am a professor in the industrial and manufacturing engineering department at Oregon State University. A copy of my current *curricula vitae* is attached.

II. I have read and understood the referenced application as filed. I also have reviewed the Office action dated December 6, 2002, issued concerning this application, as well as Epstein, U.S. patent No. 5,932,940 (Epstein) and Glassman, U.S. patent No. 4,647,748 (Glassman). I understand that the claims of the present application as currently pending are rejected as allegedly being taught by Epstein, or are considered obvious over Epstein in combination with Glassman. I disagree that Epstein and/or Glassman teaches or suggests the features of the presently claimed invention for the reasons set forth in previous papers filed with the Patent Office concerning this application, and for the additional reasons stated below.

III. All of the examples that Epstein provides for releasing a substructure from a structure are for single layers that are explicitly on the outside of a bonded lamina stack. See, for example, Epstein, column 49 line 17-25; column 52 line 29-36; column 55, line 25; column 56 lines 18-20. Embodiments of the methods disclosed in the present application can be used in this manner as well. However, the claimed invention is uniquely differentiated from Epstein in that such method allows a bonded substructure to be made from one or multiple layers on the interior

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of the laminated stack. Epstein's disclosed method cannot be used to make a freestanding substructure internal to a device post-bonding.

IV. Moreover, Epstein's devices include 10 or fewer layers. Releasing one layer at a time therefore may not be burdensome. While the present method as claimed can be used to make devices requiring 10 or fewer lamina, it more importantly can be used to make devices that require using many more than 10 lamina. In fact, devices have been made having over one thousand layers. Epstein's method requires bonding one layer at a time at the surface of the bonded stack, releasing any substructures from structures on an external layer that are required to make an operative device, bonding the next layer, releasing structures from substructures, and so on. Releasing substructures from structures on each layer according to Epstein's disclosure is impractically burdensome and uneconomical as the number of layers required to construct a working device increase. The presently claimed method allows completely bonding an entire stack and then releasing all substructures from structures on internal laminae afterward.


V. Most of the release mechanisms disclosed and claimed in the present application require materials that conduct electricity. Generally speaking, the claimed embodiments of the present method start by patterning and bonding together thin laminae of bulk, polycrystalline metals. Independent claims 1, 28 and 34 of the present application are being amended to recite using non-thin film metal or metal alloys. The references to metals in Epstein are always in the context of thin film metals (e.g. column 13, lines 6-14). Further, all of the examples that Epstein provides for materials are micromachineable materials like semiconductors or thin film metals (e.g. column 12 lines 41, 60-67). It is well known in the art that the properties of thin film metals are much different than the properties of bulk metals. Moreover, thin films must be supported by a substrate, whereas the metal laminae we are referring to have enough stiffness to stand alone. Limiting the process claims of the present application to be directed to using bulk metals and metal alloys further distinguishes Epstein.

VI. Overall, Epstein discloses a completely different fabrication architecture than claimed by the present application. Epstein bonds together a few layers of silicon and thin film materials (which are very expensive) in order to produce a great deal of precision in the devices. Further, the elimination of fixture bridges always happens on the periphery of the laminated stack requiring a very tedious bond/etch/bond/etch ... cycle. The present application is directed to an architecture involving patterning a large number of bulk, polycrystalline metals, bonding

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them together and then releasing substructures (perhaps multilayer substructures) within the device after all layers have been bonded. This provides a much more economical method to produce massively paralleled arrays of float valves, for example, embedded within a microchannel device. Expensive micro-machineable materials, such as single crystal silicon and thin film metals, would not be used to practice for the presently claimed process embodiments. The claimed process is primarily directed to making devices much larger than Epstein's process, and making these larger devices from silicon and thin film metals would be prohibitively expensive.

VII. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name	Brian Kevin Paul	
Signature		Date 4/7/03

**INDUSTRIAL AND MANUFACTURING ENGINEERING****OREGON STATE UNIVERSITY****College of Engineering**

**PAUL, Brian K.**  
Associate Professor

**BIRTH DATE**  
July 1, 1964

**DEGREES**

- Ph.D., Industrial Engineering, The Pennsylvania State University, 1995
- M.S., Industrial Engineering, Arizona State University, 1988
- B.S., Industrial Engineering, Wichita State University, 1985

**ACADEMIC POSITIONS**

- Associate Professor, Oregon State University, 2000-present
- Assistant Professor, Oregon State University, 1995-2000
- Laboratory Instructor, The Pennsylvania State University, 1993-1995

**NON-ACADEMIC POSITIONS**

- Senior Research Engineer, Battelle Pacific Northwest Laboratories, 1994
- Research Engineer, Battelle Pacific Northwest Laboratories, 1990-1993
- Manufacturing Consultant, McDonnell Douglas Helicopter Company, 1989
- Manufacturing Systems Engineer, Honeywell Industrial Automation Systems, 1986-1989
- Industrial Engineer, Boeing Military Airplane Company, 1986

**FIELDS OF SPECIALIZATION**

- Bulk microfluidic device development
- Multi-scale fabrication
  - Microlamination
  - Laser Micromachining
  - Laser Microwelding
- Material Joining
  - Diffusion Bonding/Soldering/Brazing
  - Rapid Solidification Joining

**PROFESSIONAL SOCIETIES**

- Society of Manufacturing Engineers
- American Society for Precision Engineering
- Institute of Industrial Engineers

**PROFESSIONAL ACTIVITIES**

- Associate Editor, *J Mfg Processes/J Mfg Systems*
- Associate Editor, *J Design and Mfg Automation*
- Technical Reviewer for *Intl J Mechatronics and Computers and Industrial Engineering*
- Technical Reviewer for several manufacturing-related books including *Simultaneous Engineering* and *Production Planning and Inventory Control*
- Society of Manufacturing Engineers, Student Chapter Advisor, 1996-2002

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### PROFESSIONAL RECOGNITION

- 2000 Harned K. Eldin National Young Faculty Award in Industrial Engineering, presented at the 5th Int'l Conf. on Engineering Design and Automation.
- 2000 Engelbrecht Young Engineering Faculty Award, OSU College of Engineering
- 1999 National Academy of Engineering Frontiers of Engineering Workshop, one of 35 invited academicians
- Invited Presenter at invitation-only DARPA Workshop entitled "Microchemical Systems and Their Applications", 1999
- Office of Naval Research Young Investigator, 1998-2001
- Pacific Northwest National Laboratory Affiliate Staff Scientist, 1997-2001
- Invited Speaker at *ASM Materials Solutions '97*, "Additive Freeform Microfabrication"
- Society of Automotive Engineers Doctoral Fellowship, 1992-1995
- Benjamin Niebel Manufacturing Fellowship, 1992-1993
- Honeywell Industrial Fellow in Computer-Integrated Manufacturing, 1986-1988

### PUBLICATIONS

#### Book Chapters

- Paul, B.K., "Microelectronic Manufacturing and Electronic Assembly," in *Materials and Processes in Manufacturing*, 9<sup>th</sup> Ed., DeGarmo, Black and Kohser (Eds.), Prentice-Hall, in press.
- Paul, B.K., "Rapid Prototyping and Freeform Manufacturing," in *Materials and Processes in Manufacturing*, 9<sup>th</sup> Ed., DeGarmo, Black and Kohser (Eds.), Prentice-Hall, in press.
- Paul, B.K., "Non-Traditional Machining," in *Materials and Processes in Manufacturing*, 9<sup>th</sup> Ed., DeGarmo, Black and Kohser (Eds.), Prentice-Hall, in press.
- Paul, B.K. and C.O. Ruud, "Rapid Prototyping and Freeform Manufacturing," in *Integrated Product, Process and Enterprise Design*, B. Wang (Ed.), Chapman & Hall, London, England, 1997.
- Levine, L.O. and B.K. Paul, "Implementing Technology to Enhance Agility," in *The Transition to Agile Manufacturing: Staying Flexible for Competitive Advantage*, J.C. Montgomery and L.O. Levine (Eds.), American Society for Quality Control, Milwaukee, WI, 1995.
- Spiker, B.K. and B.K. Paul, "Change and Manufacturing People," in *Success Factors for Implementing Change: A Manufacturing Viewpoint*, K. Blache (Ed.), Society of Manufacturing Engineers, Dearborn, MI, 1988.

#### Journal Publications

- Paul, B.K., H. Hasan, J.S. Thomas, R.D. Wilson, and D. Alman, "Limits on fin aspect ratio in two-fluid microchannel arrays," submitted to *J. Mfg Proc.*
- Paul, B.K., W. Wangwatcharakul and C. Wu, "A micro-ball-float valve for biological tissue-based microfluidic systems," accepted by *J. Design Mfg Automation*.
- Paul, B.K. and V. Voorakarnam, "Effect of Layer Thickness and Orientation Angle on Surface Roughness in Laminated Object Manufacturing," *J. Mfg Processes*, 3(2): 94-101, 2001.
- Paul, B.K., R.D. Wilson, E. McDowell, and J. Benjarattananon, "A study of weld strength variability for automating the capacitor discharge welding process," *Sci. Tech. Weld. Joining*, 6(2): 109-115, 2001.
- Paul, B.K., W. Thaneepakorn, and R. Wilson, "The effect of capacitor discharge welding on single crystal metals," *J Mfg. Processes*, 2(3): 143, 2000.
- Paul, B.K. and T. Terhaar, "Comparison of two passive microvalve designs for microlamination architectures," *J Micromech. Microengr.*, 10: 15-20, 2000.
- Paul, B.K., "An analytical model of the diffusive scattering of low-energy electrons in electron beam resists," *Microelectronic Engr.*, 49: 233-244, 1999.

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- Paul, B.K., R.D. Wilson, and W. Wattanuchariya, "Application of vacuum chucks to capacitor-discharge welding," *Int. J. Flex. Automation Integr. Mfg.*, 5(3&4): 203-215, 1997.
- Paul, B.K., "Effects of Gas Pressure on Low-Pressure Electron-Beam Lithography," *Scanning*, 19: 466-8, 1997.
- Paul, B.K. and M. Klimkiwicz, "Application of an Environmental Scanning Electron Microscope to Micro-Mechanical Fabrication," *Scanning*, 18: 490, 1996.
- Paul, B.K. and S. Baskaran, "A Review of Particulate Materials Processing in Additive Freeform Fabrication," *Reviews in Particulate Materials*, 4: 105, 1996.
- Paul, B.K. and Cochran, J.K., "Qualitative Modeling of the Organizational Acceptance of Advanced Manufacturing Technologies," *International Journal of Human Factors in Manufacturing*, 5(2): 177-209, 1995.
- Billo, R.E., R. Rucker, and B.K. Paul, "Three Rapid and Effective Requirements Definition Modeling Tools: Evolving Technology for Manufacturing Systems Investigations," *International Journal of Computer-Integrated Manufacturing*, 7, 3, 186-, 1993.
- Cochran, J.K. and B.K. Paul, "QUAL: A Microcomputer System for Qualitative Simulation," *Simulation*, 55, 5, 300-308, 1990.
- Paul, B.K., J.K. Cochran, and D.L. Shunk, "Prompt Communication Contributes to Success," *CIM Review*, 5, 2, 28-34, 1989.
- Billo, R. and B.K. Paul, "Human Impact of the CIM Decision," *CIM Review*, 4, 3, 37-42, 1988.

#### Refereed Conferences

- Paul, B.K., C. Aramphongphun, F. Chaplen, and R. Upson. "An Evaluation of Packaging Architectures for Tissue-based Microsystems," *Transactions of NAMRC XXXI*, Hamilton, Ontario, Canada, May 20-23, 2003.
- Paul, B.K., H. Hasan, T. Dewey, D. Alman, and R.D. Wilson, "An Evaluation of Two Methods for Producing Intermetallic Microchannels," *ASME International Mechanical Engineering Congress and Exposition*, New Orleans, LA, November 2002.
- Porter, J.D., B.K. Paul and B. Ryuh, "Cost Drivers in Microlamination based on a High-Volume Production System Design," *ASME International Mechanical Engineering Congress and Exposition*, New Orleans, LA, November 17-20, 2002, paper no. IMECE2002-32896.
- Thomas, J. and B.K. Paul, "Thermally-Enhanced Edge Registration (TEER) for Aligning Metallic Microlaminated Devices," *Transactions of NAMRC XXX*, West Lafayette, IN, May 21-24, 2002.
- Gabriel, M., B.K. Paul, R.D. Wilson, and D.E. Alman, "Characterization of Metallic Foil Joints Using Diffusion Bonding and Diffusion Soldering in Microtechnology-based Energy and Chemical Systems," *Transactions of NAMRC XXIX*, Gainesville, FL, 2001.
- Alman, D.E., R.D. Wilson, and B.K. Paul, "Fabrication of NiAl Intermetallic Reactors for Microtechnology-based Energy and Chemical Systems," *Transactions of NAMRC XXIX*, Gainesville, FL, 2001.
- Paul, B.K., H. Hasan, J. Thomas, R. Wilson, and D. Alman, "Limits on Aspect Ratio in Two-fluid Micro-scale Heat Exchangers," *Transactions of NAMRC XXIX*, Gainesville, FL, 2001.
- Paul, B.K. and R.B. Peterson, "Microlamination for Microtechnology-based Energy, Chemical, and Biological Systems," *ASME International Mechanical Engineering Congress and Exposition*, Nashville, Tennessee, AES Volume 39, pp45-52, November 15-20, 1999.
- Paul, B.K., W. Wattanuchariya, and R.D. Wilson, "Automating the Load/Unload Cycle in Capacitor-Discharge Welding," *FAIM 98*, Portland, OR, July 1-3, 1998, Begell House: New York, NY, pp. 601-610.
- Wilson, R.D. and B.K. Paul, "Automated Process Control for Capacitor-Discharge Welding," *FAIM 98*, Portland, OR, July 1-3, 1998, Begell House: New York, NY, pp. 679-690.

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- Larso, D., K. Dunn, B.K. Paul, and A. Chandrashekar, "The Relationship between Manufacturing Flexibility and Continuous Improvement: A Case Study," *FAIM 98*, Portland, OR, July 1-3, 1998, Begell House: New York, NY, pp. 227-240.
- Wilson, R.D. and B.K. Paul, "Rapid Solidification Joining of Non-Ferrous Materials," *Proceedings of the First Intl. Non-Ferrous Processing and Technology Conference*, St. Louis, MO, March 10-12, 1997, ASM Intl.: Materials Park, OH, pp. 435-443.

#### Invited Speaker

- Paul, B.K., C. Wu, W. Wangwacharakul, J. Liburdy, T. Plant, and G.N. Jovanovic, "Development of passive micro-ball valves (MBV) for biotechnology applications," ACS National Conference, San Diego, April 2-5, 2001.
- Paul, B.K., "Microlamination for Microtechnology-based Energy, Chemical, and Biological Systems," *Microchemical Systems and Their Applications*, Invitation-only DARPA workshop, 16-18 June, Washington, DC, 1999.
- Paul, B.K., "Additive Freeform Microfabrication," *ASM Materials Solutions '97*, 15-18 September, Indianapolis, IN, 1997.
- Paul, B.K. and R.D. Wilson, "Rapid Solidification Joining of Microwires," *National Academy of Sciences, Advanced Material Processing Symposium*, May 22, 1997.

#### Conference Proceedings

- Paul, B.K. and K. Kanlayasiri, "Aluminide Microchannel Arrays for High-Temperature Microreactors and Microscale Heat Exchangers," ASPE Winter 2003 topical meeting, Machines and Processes for Micro-scale and Meso-scale Fabrication, Metrology, and Assembly, January, 2003.
- Paul, B.K., H. Hasan, T. Dewey, D. Alman, and R.D. Wilson, "Development of Aluminide Microchannel Arrays for High-Temperature Microreactors and Micro-scale Heat Exchangers," *6<sup>th</sup> Int. Conf. Microreaction Tech.*, New Orleans, LA, March 10-14, 2002.
- Paul, B.K., T. Dewey, D. Alman and R.D. Wilson, "Intermetallic Microlamination for High-Temperature Reactors," *4<sup>th</sup> Int. Conf. Microreaction Tech.*, Atlanta, GA, March 5-9, 2000.
- Paul, B.K. and T. Terhaar, "Comparison of Microlamination Methods for Fabricating Two Microvalve Designs," *Industrial Engineering Research Conference*, May 22, 1999.
- Paul, B.K., R.B. Peterson, and W. Wattanachariya, "The effect of shape variation in microlamination on the performance of high-aspect-ratio, metal microchannel arrays," *3<sup>rd</sup> Int. Conf. Microreaction Tech.*, Frankfurt, Germany, April, 18-21, 1999.
- Paul, B.K. and T. Terhaar, "Comparison of Two Microvalve Designs Fabricated in Mild Steel," *3<sup>rd</sup> Int. Conf. Microreaction Tech.*, Frankfurt, Germany, April, 18-21, 1999.
- Paul, B.K. and S. Baskaran, "Issues in Fabricating Manufacturing Tooling Using Powder-Based Additive Freeform Fabrication," *Journal of Materials Processing Tech.*, 61:1-2, 168-172, 1996.
- Paul, B.K., R.D. Wilson, and J. Coleman, "Micro-Mechanical Fabrication Using Environmental Scanning Electron Microscopy," *Scanning*, 18:3, 166-168, 1996.
- Montgomery, J.C. and B.K. Paul, "Initiating Continuous Improvement within Greenfield Sites: A Federal Remanufacturing Facility Case Study," *1992 APICS Remanufacturing Conference*, Salt Lake City, UT, August 1992.
- Dixon, D.R., B.K. Paul, R.E. Billo, and T.J. Doherty, "Initiating Long-Term Modernization Programs in Large-Scale Manufacturing Environments," *AUTOFACT '90*, Detroit, MI, November 1990.
- Paul, B.K. and J.K. Cochran, "QUAL: A Microcomputer Development Environment for Qualitative Simulation," *Society of Computer Simulation Winter Conference*, San Diego, CA, January 1990.
- Paul, B.K. and B.K. Spiker, "The Future of Manufacturing Competitiveness," *Productivity through Computer-Integrated Manufacturing Conference*, Orlando, FL, December 1988.

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- Spiker, B.K. and B.K. Paul, "Managing CIM Integration: Hardware, Software, and Humanware," *Advanced Manufacturing Systems Conference*, Chicago, IL, April 1988.
- Paul, B.K., "The Development of a Practical Computer Interface for the Visually Impaired," *Human Factors Society Annual Conference*, Baltimore, MD, April 1985.

#### **Presentations**

- Jovanovic, G., S. Toppinen, T. Plant and B.K. Paul, "A Microscale Reactor System for Dechlorination of Aromatic Chlorinated Compounds in Mixed Wastes; Theory, Modeling, Design and Experiment," *4<sup>th</sup> Int. Conf. Microreaction Tech.*, Atlanta, GA, March 5-9, 2000.
- Paul, B. K., "Fabrication of Microchannels and Microvalves Using Metal Microlamination," *1<sup>st</sup> Annual Pacific Northwest Micro Energy and Chemical Systems Symposium*, August 6, 1998.
- R.D. Wilson and B.K. Paul, "Rapid Solidification Joining of Silver Electrical Contacts to Copper Conductors Using the Capacitor Discharge Welding Process," *Pacific Northwest Metals & Minerals Conference*, April 22-24, 1996.
- Paul, B.K., "The Manufacturing Role in New Product Development," University of Washington Graduate Seminar, Seattle, WA, April 1996.
- Shunk, D.L., B.K. Paul, and R.E. Billo, "Managing Technology through Effective User Needs Analysis: A Federal Government Case Study," *Third International Conference on Management of Technology*, Miami, FL, February 1992.
- Paul, B.K., "Communication: The Key to Successful Implementation," *Computer-Aided Manufacturing-International (CAM-I) Committee on Human Factors*, Chicago, IL, April 1988.
- Paul, B.K., "The Development of a Practical Computer Interface for the Visually Impaired," *Institute of Industrial Engineers Regional Student Conference*, San Antonio, TX, March 1985.

#### **Others**

- Spiker, B.K., S. Peterson, and B.K. Paul, "CIM Comes to the Process Industries," *Mechanical Engineering*, pp. 57-59, December 1988.

### **RESEARCH**

#### **Current Funded Research**

- Drost, M.K., R. Peterson, D. Pence, J. Liburdy, B. Paul, M. Kanury, V. Narayanan and P. Ge, "Development of a heat-actuated micro-scale heat pump," DoD/Army, \$1M, 7/1/02-6/30/03.

#### **Prior Funded Research**

- McFadden, P., G. Jovanovic, W. Kolodziej, J. Liburdy, B. Paul, T. Plant, F. Chaplen, and J. Trempty, "Testing and Development of the SOS Cytosensor System," Defense Advanced Research Projects Agency, \$3.0M, 2001-2004.
- Chaplen, F., P. McFadden, J. Trempty, G. Jovanovic, T. Plant, B. Paul, and J. Liburdy, "Detection of Food- and Water-Borne Pathogens through Snapshot Toxicology," National Science Foundation, \$1.2M, 1999-2002.
- Drost, M.K., R. Peterson, B.K. Paul, and J. Liburdy, "Enhancement of Heat and Mass Transfer in Mechanically Constrained Ultra Thin Films," DOE-EE, \$930,000, 2001-2002.
- Jovanovic, G., P. Watson, W. Rochefort, B. Paul and C-H. Chang, "Steam Reforming in Micro-reactors for Destruction of Hazardous Organic Materials", INEEL, \$96,000, 2001-2002.
- McFadden, P., G. Jovanovic, W. Kolodziej, J. Liburdy, B. Paul, T. Plant, F. Chaplen, and J. Trempty, "The SOS Cytosensor System - Phase II," Defense Advanced Research Projects Agency, \$549K, 2001.
- Paul, B.K., "Metal Microlamination for Energy and Chemical Systems Miniaturization," Office of Naval Research Young Investigator Program, \$301,000, 1998-2001.



PAUL, Brian K.  
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- Billo, R., D. Kim, D. Jensen, M. Hacker, and B. Paul, "Discrete Event Simulation of FMF CB Shop Consolidation Project's Conceptual Design," Royal Canadian Navy, \$276,024, 2001.
- McFadden, P., J. Trempy, F. Chaplen, G. Jovanovic, T. Plant, B. Paul, and J. Liburdy, "The SOS Cytosensor System," Defense Advanced Research Projects Agency, \$740,000, 1999-2000.
- Paul, B.K., "Metal Lamination for a Microchannel Intercooler System," Zess Technologies/Oregon Metals Initiative, \$22,448, 1999-2000.
- Paul, B.K., "Mechanical Characterization and Modeling of Solder Joints for the Secondary Side Reflow of Large IC Packages," Tektronix, \$36,444, 1998-99.
- Paul, B.K., "Rapid Prototyping for High-Aspect-Ratio Micromechanical Devices," SME Education Foundation, \$14,621, 1997-98.
- Paul, B.K., "Recurrent Electron-Beam Lithography," SME Education Foundation, \$13,137, 1996-97.
- Paul, B.K., "Automating the Material Loading of a Capacitor Discharge Welding Machine," Equipment Grant, \$5,000, Department of Energy Albany Research Center, 1996.
- Paul, B.K., "Micro-Scale Freeform Fabrication Using Electron-Beam Degradation of Polymers," The Pacific Northwest Laboratories (internal R&D), \$17,000, 1995.
- Paul, B.K., "Rapid Prototyping Using Solid Freeform Fabrication," The Pacific Northwest Laboratories (internal R&D), \$65,000, 1994.
- Paul, B.K., C.O. Hostick, L.O. Levine, L. Pond, and M. Adickes, "Manufacturing System Design for an Advanced Remanufacturing Facility," Toole Army Depot, \$1.7 million, 1991-1992.

#### EDUCATIONAL AND DEVELOPMENT GRANTS

- Paul, B.K., G.N. Jovanovic and T.K. Plant, "Development of Capture Dots and Micro-Ball-Valves for Microtechnology-Based High-Throughput Screening Devices," College of Engineering, \$50K, 1999-2000.
- W.H. Warnes, R. Busch, and B. Paul, "Automatic Metallographic Polisher and Advanced Image Analysis System," \$10,500, 2000.
- Michelle K. Bothwell, Courtney S. Campbell, Frank W.R. Chaplen, Mark F. Costello, Wilson C. Hayes, Goran N. Jovanovic, Michael E. Kassner, James A. Liburdy, Phillip N. McFadden, Joseph McGuire and Brian K. Paul, "Bioengineering Program Enhancement at Oregon State University," The Whitaker Foundation, \$2.4 million, 1999-2002.
- Peterson, R.B., B.K. Paul and T.K. Plant, "Equipment Grant for Supplementing a Microlamination Laboratory," OSU Research Office/College of Engineering, \$95,000, 1999.
- Peterson, R.B., B.K. Paul and T.K. Plant, "Energy Systems Miniaturization," OSU College of Engineering, \$14,765, 1999.
- Jovanovic, G., J. Zaworski, T.K. Plant and B.K. Paul, "Microscale Electrochemical Reactor," OSU College of Engineering, \$13,800, 1999.
- Liburdy, J., J. Zaworski, D. Pence, B.K. Paul and P. McFadden, "Microfluidic Mixing Chamber," OSU College of Engineering, \$8,500, 1999.
- Paul, B.K. and E. McDowell, "Integration of Coordinate Measuring Machine into the Manufacturing Engineering Curriculum," SME Education Foundation, \$23,000, 1998-99.
- Paul, B.K., "Metal Microlamination for Energy and Chemical Systems Miniaturization," OSU Research Office, \$7,999, 1998.
- Paul, B.K., "The Use of Electrochemical Micromachining for Mass Producing Arrays of Microflapper Valves," Pacific Northwest National Laboratory, \$7,500, 1997.
- Paul, B.K., "An Injection Molding Laboratory for Teaching New Product Development," IBM, \$15,000, 1997-98.
- Paul, B.K. and D.G. Ullman, "Beta Testing of Product Realization Consortium Educational Modules," NSF Product Realization Consortium, \$10,000, 1997-98.

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- Paul, B.K., "Integration of Rapid Prototyping into the Manufacturing Engineering Curriculum," SME Education Foundation, \$13,588, 1997-98.
- Paul, B.K., "Proposal Development for Metal Microlamination," OSU Research Office, \$5,500, 1997.
- Paul, B.K., "Fabricating Controlled Surface Roughness for Microthermal Systems Research," Pacific Northwest National Laboratory, \$6,500, 1996.
- Paul, B.K., "Redefining the Manufacturing Engineering Role in Concurrent Engineering," IBM, \$14,000, 1996-97.
- Paul, B.K. and T.G. Beaumariage, "Beta Testing of Product Realization Consortium Educational Modules," NSF Product Realization Consortium, \$10,000, 1996-97.
- Paul, B.K. and S. Baker, "Development of a Production Engineering Laboratory Based on Context Learning Principles," SME Education Foundation, \$54,108, 1996-97.
- Paul, B.K., "Concurrent Engineering Design: 3-Dimensional Modeling, Analysis, and Manufacturing Workshop," NSF Undergraduate Faculty Enhancement, \$600, 1996-97.
- Paul, B.K. and S.U. Randhawa, "Integration of Product Realization into the Undergraduate Engineering Curriculum," NSF Product Realization Consortium, \$8,281, 1995-96.

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